Available online at www.sciencedirect.com
ScienceDirect
Renewable and Sustainable Energy Reviews
11 (2007) 543–549
RENEWABLE & SUSTAINABLE ENERGY REVIEWS
www.elsevier.com/locate/rser

Design and performance of a simple single basin solar still

Muhammad Ali Samee, Umar K. Mirza*, Tariq Majeed, Nasir Ahmad

Pakistan Institute of Engineering and Applied Sciences (PIEAS), P.O. Nilore, Islamabad 45650, Pakistan

Received 17 March 2005; accepted 18 March 2005

Abstract

The lack of potable water poses a big problem in southern and south-western arid regions of Pakistan. The underground water, where exists, is usually brackish and cannot be used as it is for drinking purposes. Pakistan lies in high solar insolation band and the vast solar potential can be exploited to convert saline water to potable water. The most economical and easy way to accomplish this objective is using solar still. A simple single basin solar still was designed for 33.3° N latitude. The optimum inclination of glass cover was calculated to be 33.3° for both summer and winter. The average daily output of solar still based on data of 8 days in July 2004 was found to be 1.7 liters/day for basin area of 0.54 m^2. Efficiency of the still was calculated as 30.65% with a maximum hourly output of 0.339 liters/hr at 1300 hrs. The drinking water coming from Simly dam filtration plant, Islamabad was desalinated in the solar still. The total dissolved solids (TDS), conductivity and pH of this surface water were measured as 370 ppm, 1.291 mS/cm and 6.72 before desalination and 30 ppm, 41 μS/cm and 6.5 after desalination respectively. The ground water of PIEAS colony, Islamabad was also desalinated and results obtained were 544 ppm, 1.668 mS/cm and 6.78 before desalination and 84 ppm, 31 μS/cm and 5.74 after desalination. A lab-prepared water sample was desalinated as well and results were, 17663 ppm, 85.3 mS/cm, 7.58 before desalination and 226 ppm, 88.5 μs/cm, 6.13 respectively, after desalination. The values for TDS and pH agree with the WHO guidelines for drinking water quality.

Keywords: Single basin; Solar still; Pakistan

*Corresponding author. Tel.: +92 51 2207381, fax: +92 51 9223727.
E-mail addresses: mirzauk@yahoo.com, umar@pieas.edu.pk (U.K. Mirza).

1364-0321/$ - see front matter
doi:10.1016/j.rser.2005.03.003

Contents

1. Introduction

Over a billion people worldwide lack access to sufficient water of good quality [1]. Most of these people live in Asia and Africa. Groundwater has always been considered the best source of sufficient clean drinking water. However, in large areas worldwide, groundwater is unfit for consumption and other domestic uses due to high levels of salt.

2. Groundwater situation in Pakistan

Most of Sindh and large parts of Punjab Province of Pakistan have brackish to saline groundwater. The origin of this groundwater goes back 70 million years, to the end of continental drift of the subcontinent, which resulted in the formation of the Himalayan mountain ranges and subsequent formation of several basins. The Indus basin is considered to be a rift valley, converted into a flat plain by centuries-long alluviation. Frequent intrusions by the sea and an alluviation process have led to brackish groundwater in most parts of the Indus plain [1].

Data on groundwater in Pakistan show a gradual increase in groundwater salinity from north to south. The North-West Frontier Province (NWFP) has the smallest area ($< 1\%$) affected by groundwater salinity while the Sindh Province has the largest area, with over 85 percent of its total land area, affected by brackish groundwater [1]. The province of Balauchistan is relatively salinity free but it suffers from shortage of groundwater resources.

3. Scope for solar desalination

Solar water desalination is a technology with a very long history. Documented use of solar stills began in the sixteenth century. An early large-scale solar still was built in 1872 to supply a mining community in Chile with drinking water [2].

Solar desalination has wide application for the populations living in rural areas of southern Punjab and Sindh. Further, along the coastline in Balauchistan, sea water is abundant but potable water is not available. Solar energy can be used to convert the available saline water into potable water economically. Pakistan has vast potential as far as utilization of solar energy is concerned. The mean solar insolation falling on horizontal

surface in Pakistan is about 200-250 watt per m^2 with about 1500-3000 sunshine hours in a year [3]. Two plants consisting of 240 stills each with a capacity to clean 6000 gallons of seawater per day have been installed in Gawadar in Balauchistan. A number of such schemes are under active consideration by local governments in Balauchistan and Thar Desert region of Punjab and Sindh [4]. The solar desalination technology is simple, low cost and low-tech, and therefore, it can easily be adopted by local rural people.

4. Single basin solar still

The single basin stills have been much studied and their behavior is well understood. They remain the only design proven in this field. Efficiencies of 25% are typical [2]. The basic solar still consists of a deep basin, lined with a black waterproof material to hold the water to a depth of 5–20 cm and a cover, which is transparent to solar radiations [5]. The solar radiations transmitted by the cover are absorbed by the basin liner, which increases the water temperature and vapor pressure. The water vaporizes and loses heat to the cover by evaporation, convection and radiation, and by conduction to the base and walls of the solar still. The vaporized water is condensed along the cover material transferring the heat of condensation to the ambient air and flows down to the bottom of sloped cover and is collected in the water channel for use. The water can be fed continuously or it could be intermittent but the quantity of water in the basin should be twice the fresh water produced daily. In the Northern Hemisphere, the still is placed due south with long axis facing East-West direction. Total daily output of the solar still decreases with increasing water depth, but overnight output increases with an increase in water depth, which contributes considerably towards the total daily output [6].

5. Design of the solar still

A schematic diagram of the designed solar still is shown in Fig. 1. The actually fabricated solar still is shown in Fig. 2. The basin area of the still is 0.54 m^2, fabricated using galvanized iron sheet of 18 gauge thickness. The bottom and sides of the basin are insulated by 3 cm thick thermo pore sheet surrounded by a wooden frame of 2 cm thickness. The surface of the basin is painted black to absorb maximum solar radiations

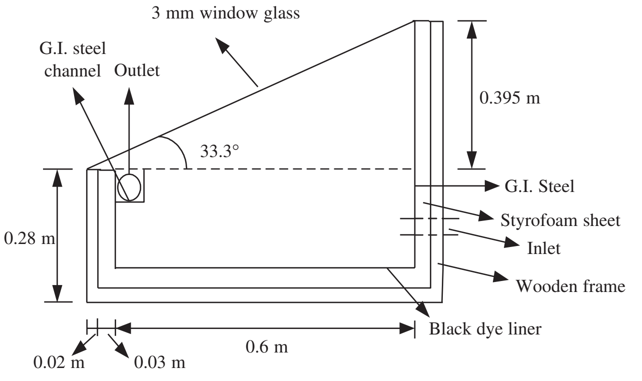

Fig. 1. Schematic diagram of the designed single basin solar still (drawn not to scale).

Fig. 2. The fabricated solar still being tested in outdoor conditions.

Table 1
Output of Solar Still

Date	Day Time (liters)	Night Time (liters)
20 July	1.00	0.45
21 July	1.45	0.55
22 July	1.44	0.35
23 July	1.40	0.29
24 July	1.40	0.50
25 July	1.30	0.25
26 July	1.35	0.29
27 July	1.31	0.27

because it is an established fact that black dye is the best solar radiation absorbing material. The cover of the still is made up of 3 mm thick simple window glass, making an angle of 33.3° with horizontal, optimized for 33.3° N latitude of Islamabad. This follows the general rule of thumb that the glass cover angle should be latitude + 10° for winter and latitude-10° for summer for a particular location [7]. The fresh water is collected in a galvanized iron channel fixed at the lower end of the glass cover and is taken out through an outlet nozzle. A PVC pipe is used to supply the brackish water through the inlet nozzle. The whole system is made vapor-tight using silicone rubber as sealant, because it remains elastic for quite long time.

6. Performance evaluation

The solar still was tested outdoors at PIEAS, Islamabad (see Fig. 2). Table 1 gives the daily, day-light and overnight output of the still in the month of July 2004. The average daily output was found to be 1.7 liters/day for basin area of 0.54 m^2 based on data of 8 days. The literature tells us that efficiently designed solar stills have daily output of the order of 4 liter/m^2 in high insolation areas [8]. Fig. 3 shows the total output graphically.

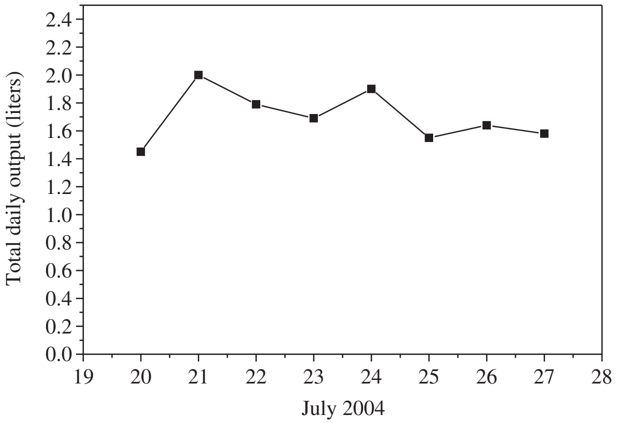

Fig. 3. Total daily output of the still.

Table 2
Day Time Variation in the Output of Solar Still

Time (hours)	Ambient Temperature (°C)	Output (litres)
1000	38	Start of measurement
1100	42	0.063
1200	40	0.293
1300	39	0.339
1400	40	0.330
1500	38	0.292
1600	38	0.248
1700	36	0.122
1800	34	0.130
1900	32	0.124

The efficiency of the solar still was calculated using the formula given in literature [2] and it came out to be 30.56%. The solar stills installed in the different parts of the world have efficiencies of the order of 30-40% [9]. Efficiency of the solar still can be improved by providing more efficient insulation in order to keep the heat loss to a minimum.

The output of the solar still varies directly with the amount of insolation it gets and the ambient temperature. The hourly output of the solar still was measured on 4 August 2004, and the values are shown in Table 2. The hourly output is maximum in afternoon hours when the ambient temperature is at its daily peak.

Another aspect which needed attention was quality of desalinated water. Three parameters are important in this regard: total dissolved solids (TDS), pH and electrical conductivity. Higher values of conductivity indicate presence of more dissolved solids and hence more salinity. Three different water samples were desalinated and tested for these parameters. Sample one was taken from drinking water supply coming from Simly Dam, located near Islamabad. Second water sample consisted of the groundwater obtained from PIEAS colony. A highly turbid and saline third sample was prepared in laboratory. All

Table 3
Tested Water Quality Parameters

Sample no.	TDS (mg/liter)		pH		Conductivity (mS/cm)	
	Before desalination	After desalination	Before desalination	After desalination	Before desalination	After desalination
Sample 1	370	30	6.72	6.50	1.291	41.0×10^{-3}
Sample 2	544	84	6.78	5.74	1.668	31.0×10^{-3}
Sample 3	17,663	226	7.58	6.13	85.3	88.5×10^{-3}

Table 4
Cost Estimation for the Components

Component	Cost in Pakistan (Rs.)
Wooden container	2950
G. I. container	1200
Glass cover	240
Inlet, outlet nozzles	200
Float valve	45
Paint	200
Styrofoam sheets	105
Handles	100

three parameters—TDS, pH and conductivity—were measured for the three samples before and after they were desalinated. The results are presented in Table 3.

According to WHO Guidelines for Drinking-water Quality [10], the palatability of water with a TDS level of less than 600 mg/liter is generally considered to be good; drinking-water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/litre. The presence of high levels of TDS may also be objectionable to consumers, owing to excessive scaling in water pipes, heaters, boilers and household appliances. However WHO does not propose any health-based guideline value for TDS. The TDS values for all three samples after desalination fall well within the 600 mg/liter level. No health-based guideline value has been proposed by WHO for pH either. Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters. The optimum pH required varies in different supplies according to the composition of the water and the nature of the construction materials used in the distribution system, but it is usually in the range 6.5–8 [10]. The pH of the samples after desalination is not far off from these values.

7. Cost estimation

In designing a solar still for principally rural communities, the prime objective was to keep the cost as low a possible. Cost estimation for various components is given in Table 4. The cost of fabrication was about Rs. 1000. The total cost of fabricated still comes out to be Rs. 6040 (~US$100). It is expected that cost would substantially decrease if a large number of still are fabricated.

8. Conclusion

A single basin solar still was fabricated and tested. The optimized glass cover angle was 33.3° for PIEAS, Islamabad (33.3° N latitude). The efficiency was calculated as 30.56% which is comparable with stills being used worldwide. The cost effective design is expected to provide the rural communities an efficient way to convert the brackish water into potable water.

Acknowledgements

The authors are grateful to and properly acknowledge the help of the organizations whose literature has been cited in this article. One of the authors (Umar K. Mirza) is especially grateful to Higher Education Commission of Government of Pakistan for providing him a scholarship to carry out Ph.D. studies at PIEAS.

References

[1] Ensink JHJ, Aslam MR., Konradsen F, Jensen PK., van der Hoek W. Linkages between irrigation and drinking water in Pakistan. Working Paper 46. Colombo, Sri Lanka: International Water Management Institute; 2002.

[2] Intermediate Technology Development Group. Solar distillation: Technical brief. Rugby, UK: The Schumacher Centre for Technology & Development. http://www.itdg.org/docs/technical_information_service/solar_distillation.pdf (accessed on 14 March 2005).

[3] Mirza Umar K. Mercedes Maroto-Valer, Nasir Ahmad. Status and outlook of solar energy use in Pakistan. Renewable and Sustainable Energy Reviews 2003;7:501–14.

[4] World Energy Council. Renewable energy in South Asia: Status and prospects. London, UK; 2000.

[5] Applications of solar thermal energy: Liquid systems, Kumar S, Attalage RA. Pathumthani, Thailand: Asian Institute of Technology. http://www.courses.ait.ac.th/ED06.22/course1/lecs/module3/m31o98.html (accessed on 14 March 2005).

[6] Aboul-Enein S, El-Sebaii AA, El-Bialy E. Investigation of a single-basin solar still with deep basins. Renewable Energy 1998;14(1–4):299–305.

[7] Harris Norman C, Miller Cydney E, Thomas Irving E. Solar Energy Systems Design. New York: Wiley; 1985.

[8] Solar Humidification, http://www.serve.com/damien/home/solarweb/desal/solarstill.html (accessed on 15 March 2005).

[9] Jenny Lindblom. Solar thermal technologies for seawater desalination: state of the art. Renewable Energy Systems, Luleå University of Technology, Sweden. http://energi.fysikk.uio.no/rebus/phd_2003/SOA-Seawater_desalination.doc (accessed on 15 March 2005).

[10] WHO. Guidelines for drinking-water quality, recommendations. vol. 1. Switzerland, Geneva: World Health Organization; 2004.